Natural Ferromagnetic Resonance in Microwires

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Abstract - The investigation of ferromagnetic metal microwire with an amorphous core structure by ferromagnetic-resonance method is reviewed. This method can be used in investigation the residual stress and the micro- and macroscopic heterogeneity of amorphous materials. The theoretical basis of the method in this case is considered.

Index Terms - ferromagnetic-resonance method, cast amorphous glass-coated microwires, residual stress.

1. INTRODUCTION

A microwire was considered as ferromagnetic cylinder with small radius $r_m$. For its characterization we introduce following parameters:

1. The depth of the skin layer is:
   \[ \delta = \left[ \frac{4\pi \mu_0 \sigma}{\mu_e} \right]^{1/2} = \delta_0 \left( \frac{\mu}{\mu_0} \right)^{1/2}, \]
   \( \mu_0 \) - is the effective magnetic permeability, and \( \sigma \) - is the microwire electrical conductivity. In the case of our magnetic microwires, with the relative permeability \( \mu \sim 10^2 \), \( \omega \sim (8 - 10) \text{ GHz} \) \( \delta \) changes from 1 up to 3 \( \mu m \).

2. The size of the domain wall (according to Landau-Lifshits theory) is:
   \[ \Delta = \pi (A/K)^{1/2} \sim 10 - 0,1 \ \mu m, \]
   where \( A \) is the exchange constant and \( K \) is the energy anisotropy of microwire.

3. Radius of single domain (according to Brown theory) is:
   \[ a = \left( \frac{1,84}{M_s} \right) \left( \frac{A}{2\pi} \right)^{1/2} \sim 0,1 - 0,01 \ \mu m, \]
   where \( M_s \) is the saturation magnetization of microwire.

According to the frequency of the NFMR is:

\[ \frac{\omega}{\gamma} = (H_e + 2 \pi M_s)^2 - (2 \pi M_s)^2 \exp\{-2\delta/r_m\}, \]

where \( \gamma \) is the gyromagnetic ratio \( (\gamma \sim 2,8 \text{ MHz/Oe}) \). The anisotropy field is \( H_e \sim 3\lambda \sigma /M_s \), where \( \lambda \) is the magnetostriction constant; and \( \sigma \) is the effective residual stress originated from the fabrication procedure.

2. CONCLUSION

For the frequency of NFMR in simple approximation formula can be written as:

\[ \omega (GHz) \approx \omega_0 \left( \frac{0.4x}{0.4x+1} \right)^{1/2}, \]

\( x \) is ratio of the glass - metal cross-sectional area,

\[ \omega_0 (GHz) \approx 1.5 \left( \frac{\lambda}{10^6} \right)^{1/2} \]

Fig. Theoretical curve (continuous curve) of FMR frequency as a function of \( x \) according to Eq. (1), for zero external field and experimental data for dependence of FMR frequency on parameter \( x \) (crosses)